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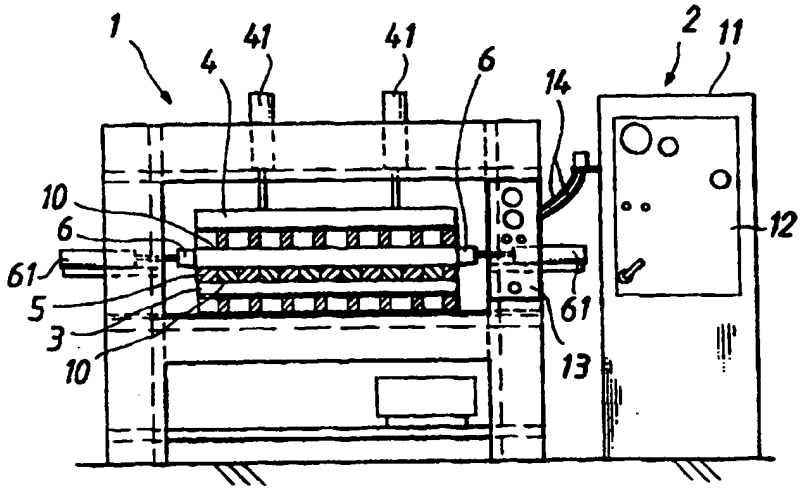
(54) Title: METHOD AND APPARATUS FOR BENDING INTEGRAL WOOD



(57) Abstract

A method for bending integral wood, in which method the wood blanks (5) are heated and compressed in the direction of the longitudinal axis of the grain or fibers, whereby the wood blank (5) becomes more pliable to bend, the wood blank is bent to a desired shape and the wood blank is finally dried. The heating step and the compression step of the wood blanks (5) in the direction of the grain of fibers (plasticization) are performed synchronously so that an electric field is generated and aimed through the wood blanks (5) and the wood blanks are compressed in the direction of the grain or fibers, and the bending step and the drying step are performed synchronously so that the wood blank (5) bent to the desired shape is heated by means of an electric field in a bending unit to a temperature in the range 230 - 250 °C, whereby the shape of the bent wood blank remains essentially irreversibly permanent. The invention also concerns an apparatus suited to implement the method.

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Method and apparatus for bending integral wood

The present invention is related to a method in accordance with the preamble of claim 1 for bending integral wood. The invention also concerns an apparatus in accordance with the preamble of claim 6 suited for implementing the method.

Conventionally, wood blanks can be bent in a direction perpendicular to the longitudinal axis of the wood fibers and grain after a pretreatment of the wood by steaming or cooking, followed by compression along the longitudinal axis of the grain or fibers with simultaneous compressive backing at the sides to prevent bending of the blank. Subsequently, the blanks are conventionally bent to a desired shape with the help of diverse bands and jigs, after which the bent shapes are dried in a separate kiln.

Among other things, a disadvantage of such methods is that heating the wood blank by means of steaming and cooking is a cumbersome and time-consuming process. The moisture content absorbed into the wood becomes high, 30 - 60 %. Moreover, a substantial amount of energy is consumed in the heating and pumping of the medium employed to transfer heat to the wood. Further, the high moisture content, high temperature and long heating time cause undesirable color changes particularly in light-colored wood grades. Finally, such equipment require a large installation space.

It is an object of the present invention to achieve a method and an apparatus suited to implement the method, both capable of overcoming the drawbacks of the prior-art techniques. It is a particular object of the invention to provide a method according to which integral wood with a thickness advantageously typically greater than 2.7 mm can be bent to a permanent shape using the most common

timber grades employed in the furniture and joinery industries.

The method according to the invention is characterized by what is stated in the characterizing part of claim 1. Furthermore, the preferred embodiments of the method according to the invention are characterized by what is stated in the characterizing part of claims 2 - 5.

The apparatus according to the invention is characterized by what is stated in the characterizing part of claim 6.

The invention according to the present patent application offers a plurality of significant advantages. As multiple workphase can be performed in a single step, the workpiece throughput time is shortened resulting in a faster process. Need for further machining is reduced thus obviating investments in machinery. Material savings in blanks can be as high as 50 %. No separate kiln is required for drying. Wood retains its original color and remains free from splits and warps. Product quality is improved as the method can use thin boards sawn from low-defect sapwood. As the drying process does not cause splits, manufacturing of bent large-area integral-wood objects becomes possible.

In the following, the invention will be examined in more detail by means of preferred exemplifying embodiments with reference to the attached drawing, in which:

Figure 1 is a front view of the plasticization unit of an apparatus according to the invention;

Figure 2 is a top view of the plasticization unit of an apparatus according to the invention;

Figure 3 is a front view of the bending/drying unit of an apparatus according to the invention;

Figure 4a is a side view representing the mold of the bending/drying unit of an apparatus according to the invention lowered to the pressing position; and

Figure 4b is a side view of representing the open position of an apparatus according to the invention.

The apparatus for bending wood blanks comprises a plasticization unit (Figs. 1 and 2) and a bending/drying unit (Fig. 3), both located close to each other. The plasticization unit comprises a press 1, whose gap is adapted to accommodate the wood blanks, and a heating apparatus 2 connected to the press. The press gap is advantageously formed by a fixed plane 3, and above that, a movable plane 4, whereby the wood blanks 5 to be processed are placed in the gap between the planes. The unit further incorporates side gages 6 which provide side support to the blanks 5 to be processed. For the actual compression at the ends, the press gap is advantageously provided with a fixed gage 7 and a compression gage 8 suited to compress the wood blanks 5 by means of an actuator arrangement 9 against the fixed gage 7. The actuator arrangement is advantageously comprised of at least one actuator cylinder. Also the actuator arrangements of the movable plane 4 and the side gages 6 are advantageously comprised of actuator cylinders 41, 61. Obviously, compression of the wood blank can alternatively be implemented by applying compression to both ends of the blank. The purpose of the movable plane 4 and the side gages 6 is to prevent the lateral deflection of the wood blanks 5 during the longitudinal end-to-end compression.

The press gap is provided with means for heating the wood blanks 5. Such means provide an electric field penetrating the wood blanks being processed. The means comprise electrodes 10, advantageously plane electrodes, which are adapted to the fixed plane 3 and the movable plane 4, for instance. The electric field is formed in a preferred embodiment by means of a radio-frequency generator 11 incorporating an oscillator, typically a self-excited triode tube oscillator. The RF generator 11 and the press 1 are controlled by means of control unit 12, 13 permitting preset adjustments for, e.g., the duration and temperature of the heating cycle, as well as the pressure, stroke length and duration of the compression cycle, and the start and stop times of both cycles relative to each other. The output current of the RF generator is taken via conductors 14 to the electrodes 10. The temperature of the wood blanks is elevated by means of the imposed RF field advantageously to 130 C in wood having a moisture content of 20 %. Then, cellular constituents of the wood of the blanks undergo a change called glass transition. The compression cycle in the longitudinal direction of the grain or fibers is started with a preset delay after the start of the heating cycle. Thus, the heating and compression cycles occur synchronized, whereby a simultaneous mechanical and electrical plasticization take place. The longitudinal compression in the direction of the grain is advantageously applied progressively during the plasticization. In an advantageous embodiment the plasticization cycle was set equal to 10 min. After 5 min from the start of the plasticization cycle, the longitudinal compression cycle is initiated increasing the pressure progressively and stabilizing at a preset value (e.g., when the relative compression reaches 2 % of the blank length), which is maintained to the end of the plasticization cycle. The moisture content of the wood blanks introduced to the plasticization process is advantageously in the range of 16 - 20 %. A blank

plasticized in the above-described manner can be bent to a radius which in practice is approx. 15 - 20 % smaller than that achievable for a nonplasticized blank. The length reduction by compression is advantageously 1 - 3 % of the blank length. The plasticization method disclosed herein is rapid, permits use of low moisture content of the blank, and achieves plasticization homogeneously in all wood blanks of the lot being plasticized. E.g., a birch blank with dimensions 30 mm x 50 mm x 900 mm can be bent to a minimum radius of approx. 800 mm using the above-described plasticization process. The plasticization process can be applied to a plurality of blanks simultaneously. Up to 20 pieces of the above-mentioned blanks can be processed in a single batch. The output rating of the RF generator in the apparatus used in the above example was 6 kW, advantageously at a frequency of 13.56 MHz.

The plasticized blanks 5 are advantageously transferred immediately after the first step to a bending/drying unit located beside the plasticization unit. The bending/drying unit comprises a press 15 incorporating a mold 16, 17 with a suitable contour for bending the blank to a desired shape. The lower part 16 of the mold is adapted onto the fixed plane 18, while the upper part 17 of the mold is adapted to the movable plane 19, advantageously moving with the plane. The plasticized wood blanks 5 are pressed into shape by the mold surfaces. In addition to bending, the plasticized wood can be irreversibly compressed radially or tangentially by up to approx. 15 % of the blank thickness. Thus, the wood blanks 5 can be ready-compressed to a correct cross-sectional shape.

The bent pieces are dried in the press 15 by applying an RF field between the compression planes 18, 19. To the compression planes, advantageously to the mold 16, 17, are adapted electrodes 20 between which the electric

field is formed. The electric field is an RF field with a frequency of 13.56 MHz, advantageously, and a power input of 12 kW, for instance. For the above-mentioned values, the drying time varies in the range 7 - 30 min depending on the size and moisture content of the pieces. Then, the amount of water expelled from the batch is from 2 l to 20 l. Owing to the evaporation of water from the wood pieces during the drying step, the moisture content of the wood was 6 - 7 % at the end of the drying process. The electric field is provided by an RF generator 21, whose output current is taken to the electrodes 20 via conductors 22.

During the drying step, the internal temperature of the wood is elevated to 230 - 250 C, whereby the wood material having undergone a glass transition during the plasticization step solidifies and the cellular structure of the wood is denatured resulting in a permanent fixation of the shaped piece. The compressed wood retains its shape in an irreversible manner. A wood piece bent and compressed in the above-described method is harder than the blank prior to the compression. This is an advantage particularly with softer wood grades. In an advantageous exemplifying case the dimensions of the pieces were 30 mm x 50 mm x 900 mm. The initial moisture content was 20 % and the final moisture content 6 %. Then, the drying time was 13.5 min. The operation of the bending/drying unit is adapted to be controlled by means of a control unit 23, 24 suited to run the bending/drying process in a programmed manner. In an apparatus according to the invention, the control range of the automatic tuning unit 23 of the RF generator is extended with the help of an adjustable trombone transmission line. Such an arrangement permits retuning of the system without stopping the drying process in the case the normal tuning range of the generator is exhausted. This is implemented through providing the shaft of the RF generator tuning

motor 25 with an element which advantageously via a limit switch 26 gives a control pulse to a trombone tuning unit 27, which controls the adjustable trombone transmission lines 28 to a new, preset position, whereby the system is shifted to a new tuning range and the automatic tuning unit of the generator can resume the initial position set for the tuning unit at the start of the drying process thus permitting the automatic control of the process to carry out the drying process to its preset end point. Obviously, the control equipment employed can be of any conventional type known in the art.

With reference to Figs. 4a and 4b, a mold suited for use in the bending/drying unit is shown. The mold is advantageously formed by two parts 16, 17 between which the wood blank is inserted. The mold surfaces facing the wood blank are adapted to accommodate electrodes 20 or equivalent means suited to launch an electric field and aim it through the wood blank. The mold upper part 17 is designed shorter than the mold lower part 16 at least in the direction of the longitudinal axis of the wood blank 5, whereby the water vapor released during drying can easier escape from the mold and the risk of arcing is reduced. The mold lower part 16 is further designed to incorporate side walls 29 resting against the edges of the wood blanks 5. The purpose of the side walls 29 is to prevent excessive bulging of the outer edge (tension edge) of the wood blank during the bending step thus improving the bending result. In Fig. 4a the mold is represented in closed compression position and in Fig. 4b in the open position.

For those versed in the art it is obvious that the applications of the invention are not limited by the embodiments described above, but rather, can be varied within the scope of the inventive spirit disclosed in the annexed claims.

Claims:

1. A method for bending integral wood, in which method the wood blanks (5) are heated and compressed in the direction of the longitudinal axis of the grain or fibers, whereby the wood blank (5) becomes more pliable to bend, the wood blank is bent to a desired shape and the wood blank is finally dried, c h a r a c t e r - i z e d in that the heating step and the compression step of the wood blanks (5) in the direction of the grain or fibers (plasticization) are performed synchronously so that an electric field is generated and aimed through the wood blanks (5) and the wood blanks are compressed in the direction of the grain or fibers; and that the bending step and the drying step are performed synchronously so that the wood blank (5) bent to the desired shape is heated by means of an electric field in a bending unit to a temperature in the range 230 - 250 C, whereby shape of the bent wood blank remains essentially irreversibly permanent.

2. A method as defined in claim 1, c h a r a c t e r - i z e d in that the wood blank (5) is compressed during the bending step so as to attain a desired cross-sectional shape.

3. A method as defined in claim 1 or 2, c h a r a c - t e r i z e d in that during the drying step the wood blanks (5) are maintained at a temperature of 230 - 250 C for 0.5 - 2.5 min, advantageously 1 - 2 min.

4. A method as defined in any of foregoing claims 1-3, c h a r a c t e r i z e d in that the electric field aimed through the wood blanks is a radio-frequency field.

5. A method as defined in any of foregoing claims 1-4, c h a r a c t e r i z e d in that during the plasticiza-

tion the wood blanks (5) are longitudinally compressed, advantageously in a progressive manner, by 1 - 3 % of the initial length of the wood blanks.

6. An apparatus for bending integral wood, said apparatus comprising heating means (2) for heating wood blanks (5), compression means (1) for compressing the wood blanks in the direction of the longitudinal axis of the grain or fibers, a bending unit (15) for bending the wood blanks (5) and heating means (21) for drying the bent wood blanks (5), c h a r a c t e r i z e d in that the heating means (2) is adapted as an integral part of the compression means (1); that the heating means comprises means (10, 11, 14) for generating an electric field and aiming it through the wood blanks (5); that the bending unit (15) is adapted to incorporate means (21) for generating an electric field and aiming it through the bent wood blanks (5); and that a mold (16, 17) of the bending unit is provided with side walls (29) to prevent excessive bulging of the tension side of the wood blank (5).

7. An apparatus as defined in claim 6, c h a r a c t e r i z e d in that said means for generating the electric field comprises a radio-frequency generator (11, 21) and suitable electrodes (10, 20) and conductors (14, 22).

8. An apparatus as defined in claim 6 or 7, c h a r a c t e r i z e d in that the mold (16, 17) of the bending unit is adapted to incorporate electrodes (20) and that one part (16) of the mold is designed shorter than the other part (17) of the mold at least in the longitudinal direction of the wood blanks (5).

9. An apparatus as defined in any of claims 6 - 8, c h a r a c t e r i z e d in that the bending unit (15)

is provided with means for shaping the cross section of the wood blanks (5) during the bending step.

10. An apparatus as defined in any of claims 6 - 9, c h a r a c t e r i z e d in that the mold (16, 17) of the bending unit is shaped to compress the cross-sectional shape of the wood blanks (5) during the bending step.

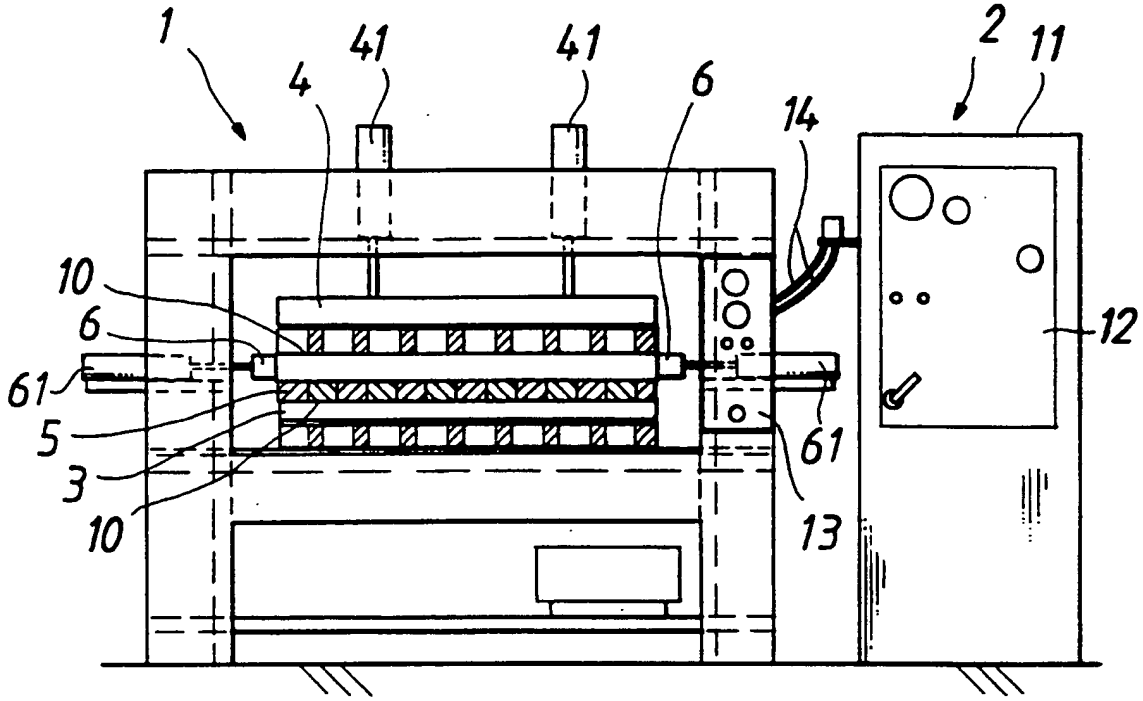

Fig.1

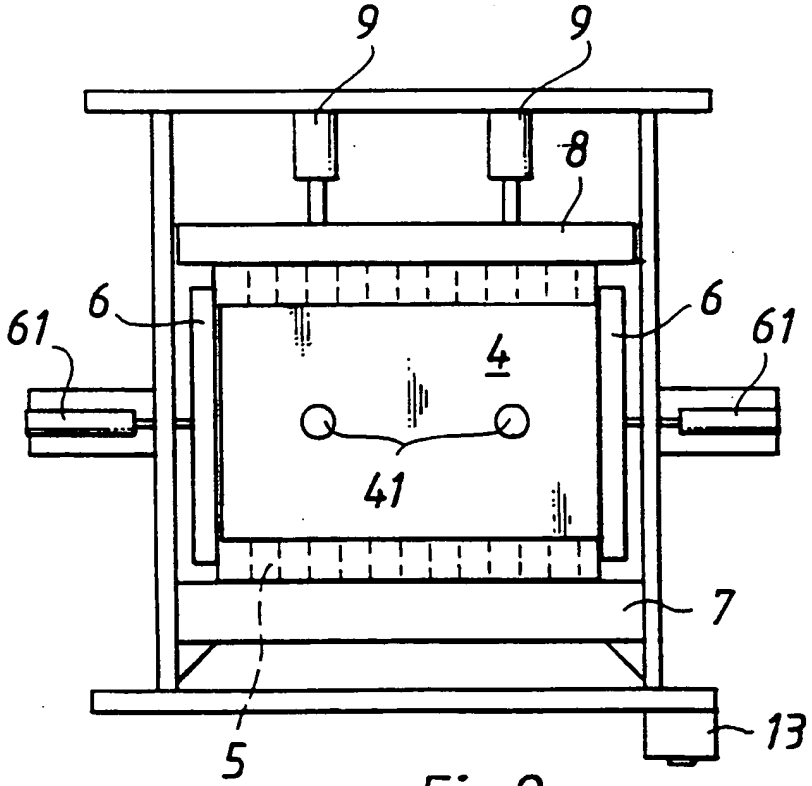

Fig.2

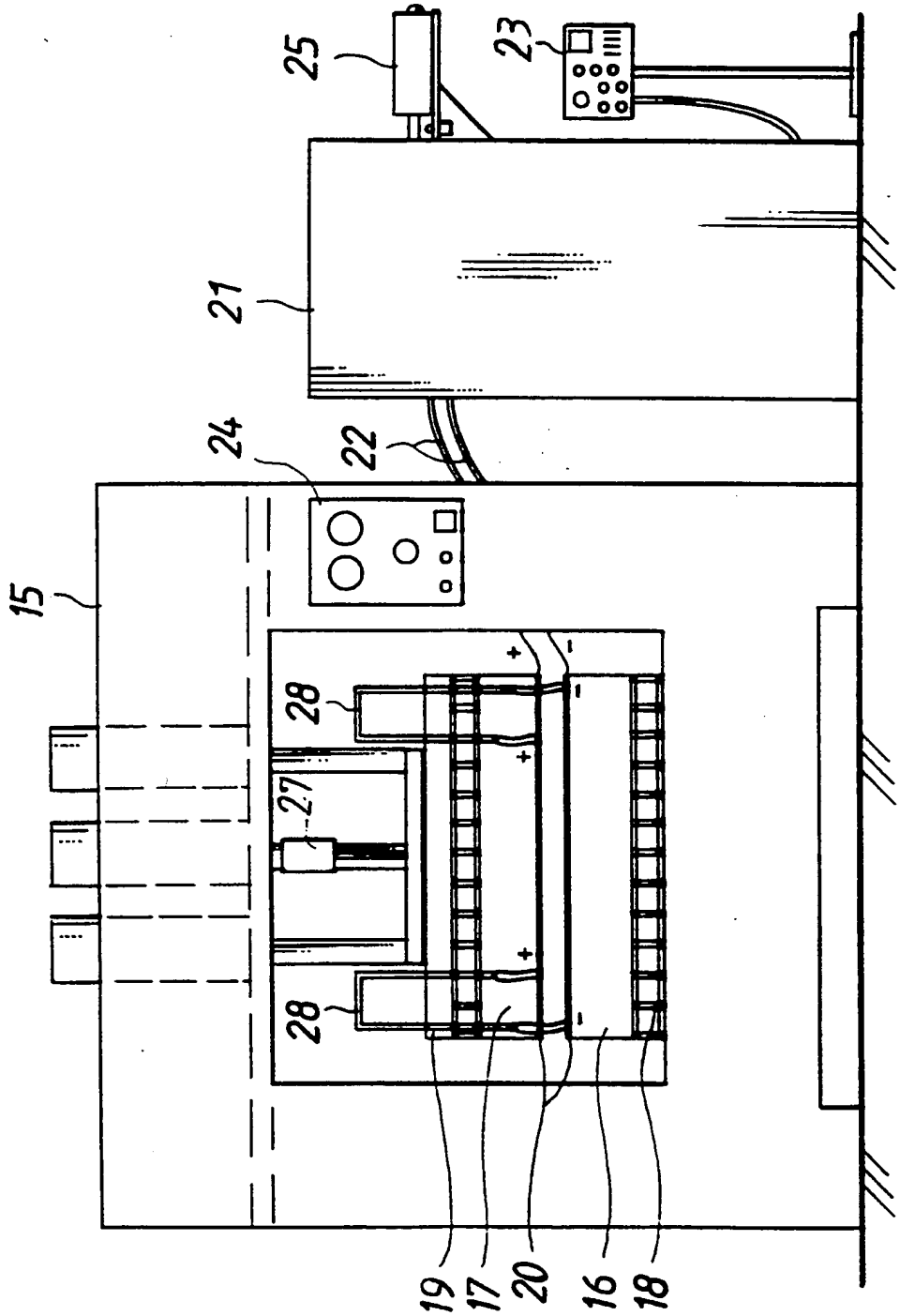

Fig.3

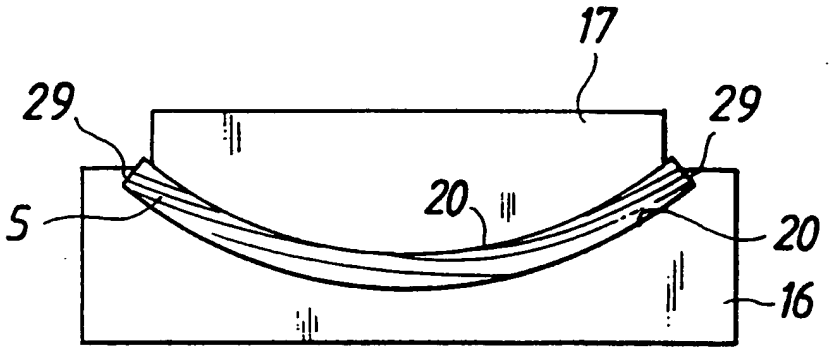

Fig. 4a

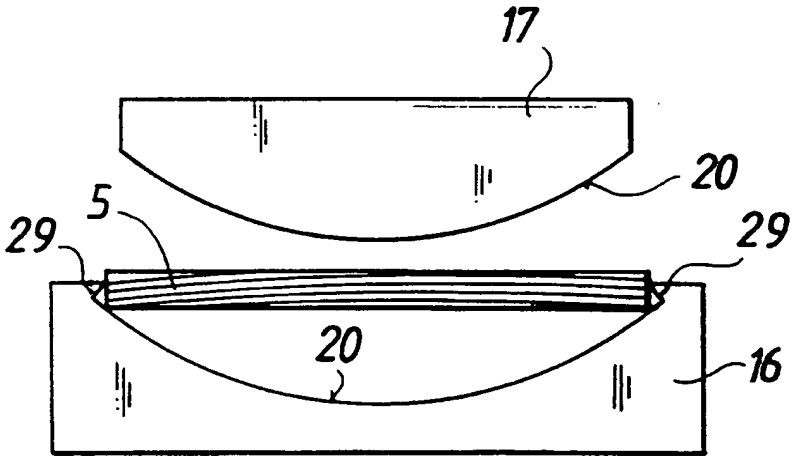

Fig. 4b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 94/00222

A. CLASSIFICATION OF SUBJECT MATTER

IPC5: B27H 1/00, B27M 1/02
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE, C1, 946479 (AUGUST THURN; AGNES THURN), 2 August 1956 (02.08.56) --	1-10
Y	DE, C1, 516801 (THE ANGLO EUROPEAN COMPANY LIMITED), 8 January 1931 (08.01.31) --	1-10
Y	DE, A1, 3106304 (TRÖBS, REINHARD), 18 February 1982 (18.02.82), page 6, line 1 - line 13, abstract --	1-10
Y	DE, A1, 3033802 (NORIMOTO, MISATO; HASEGAWA, KENJI), 22 April 1982 (22.04.82) --	1-10

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO, A1, 9102637 (DANSK TEKNOLOGISK INSTITUT), 23 August 1990 (23.08.90), page 4, line 7 - line 14; page 14, line 23 - line 26 -- --------	1-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/07/94

International application No.
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-C1- 946479	02/08/56	NONE	
DE-C1- 516801	08/01/31	NONE	
DE-A1- 3106304	18/02/82	NONE	
DE-A1- 3033802	22/04/82	NONE	
WO-A1- 9102637	23/08/90	AU-A- 6331690	03/04/91
		CA-A- 2064563	25/02/91
		EP-A- 0494172	15/07/92